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Biodiversity relationships in urban and suburban parks in Flanders

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Abstract

Urban and suburban parks can play an important role in the conservation of biodiversity, especially in a strongly urbanised region like Flanders (Belgium). A previously developed method for monitoring biodiversity was applied to 15 parks in Flanders. This method took both habitat and species diversity into account and resulted in 13 biodiversity indicators. The results show that urban and suburban parks can have a high species richness, especially if they consist of different more or less semi-natural habitats. The relationships between the biodiversity indicators and the ecological factors affecting the biodiversity were examined using multivariate analyses and correlation techniques. Park area was the main factor explaining the variation in biodiversity indicators, so larger parks could contribute more to the conservation of biodiversity than small ones. A biodiversity score based on habitat diversity and species richness was proposed to summarise and evaluate the biodiversity. This score is not correlated with the park area and is therefore considered as a reliable indicator for comparing biodiversity in parks of different area.

Keywords: Biodiversity; Monitoring; (Sub)urban parks

1. Introduction

Flanders (the northern part of Belgium) is one of the most densely populated areas in the world with 6 million people living on an area of 13,500 km^2. Hence, there is not much space for natural and semi-natural habitats: forests account for 10% of the area and nature reserves for only 1.7%. Especially in and near large cities few natural habitats are available. But Flanders also contains about 22,000 ha of urban and suburban parks. They have an average area of 7.5 ha, although 67% are smaller than 5 ha and only 8% are larger than 20 ha (Forest and Green Spaces Division, 2002). Despite their primarily recreational function, these parks can partly compensate for the lack of natural habitats in urban and suburban environments and so they may contribute to the conservation of biodiversity in Flanders.

Biodiversity research in urban and suburban parks is very limited. Most often it is restricted to a specific species group, for example, vascular plants (Kunick, 1978), mosses (De Meulder et al., 1991), bats (Kurta and Teramino, 1992), mammals (Chernousova, 1996), arthropods (Natuhara et al., 1994), dragonflies (Huys, 1988) or birds (Blanco and Velasco, 1996; Sys, 1997; Jokimäki, 1999; Morneau et al., 1999; Fernández-Juricic, 2001). The main reasons for the lack of a more generalised approach to biodiversity research are the habitat complexity of (sub)urban parks (Gilbert, 1989), the predominance of recreational and ornamental functions and the concept of biodiversity itself, which has a multi-scaled content

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going from genes, species to habitats and ecosystems (Noss, 1990; Raven, 1992; Hawksworth, 1995).

In an earlier paper (Hermy and Cornelis, 2000), we developed a method for monitoring the biodiversity in urban and suburban parks, which took both species and habitat diversity into account. In that study, the municipal park of Loppem (West-Flanders) was used as a test case to evaluate the feasibility of the method. Since then this method has been applied to 14 other parks in Flanders. In this paper, we use the results for those 15 parks (municipal park of Loppem and the 14 new ones) to explore the relationships between different indicators of biodiversity. We try to determine the most important ecological factors affecting biodiversity in parks. We also present a biodiversity score, which is a simple way for comparing and evaluating biodiversity in different parks.

2. Methods

2.1. Biodiversity indicators

The method for monitoring biodiversity in parks takes habitat diversity as well as species diversity into account and results in 13 biodiversity indicators (see Table 1). The choices of the indicators were justified in Hermy and Cornelis (2000).

To determine habitat diversity in a time-efficient way, we developed a list with 56 possible habitat units that can be found in (sub)urban parks in Flanders (see Table 1 in Hermy and Cornelis, 2000). We distinguished between planar, linear and punctual units. Punctual units have an area of maximum $100\,\mathrm{m}^2$, linear units have a length/width ratio > 10 and planar units have an area $> 100\,\mathrm{m}^2$ and a length/width ratio < 10. Using field information and/or detailed aerial photographs, the delineation of these units was determined. After digitising them in ArcView 3.2 (ESRI Inc., 1996), we computed their area, length or number. From this data the proportion (%) of the total area, length or number of habitat units in the park was calculated. With these proportions a habitat unit diversity index was computed using the Shannon–Wiener diversity index (H) (see Hermy and Cornelis, 2000):

$$H = -\sum_{i=1}^{s} \frac{n_i}{N} \ln \frac{n_i}{N}$$

where i is the ith habitat unit, s the number of habitat units, n_i the area, length or number of the ith habitat unit and N the total area, length or number in the park.

In this way, we obtained a diversity index for each “habitat” type category (planar, linear and punctual). Because such a Shannon–Wiener index is not very interpretable, we calculated the ratio between the Shannon–Wiener indices and the maximum potential diversity ($H_{\max}$). The latter is reached when all concerned habitat units are present in the park and each with the same area, length or number:

$$H_{\max} = -\sum_{i=1}^{s_{\max}} \frac{1}{s_{\max}} \ln \frac{1}{s_{\max}} = \ln s_{\max}$$

where $s_{\max}$ is the total number of distinguished habitat units.

The ratio $H/H_{\max}$ then gives the proportion of the maximum diversity for planar, linear or punctual units. This proportion varies between 0 and 1. Since we were using the total number of all possible habitat units for all parks in a region (i.e. Flanders), we interpreted this ratio as a ‘*saturation index*’. The total saturation index (S_t) for all habitat units together was calculated as a weighted average of the three separate indices. Weighting was done using the number of recorded units in the park:

$$S_t = \frac{S_{pl}n_{pl} + S_{li}n_{li} + S_{pu}n_{pu}}{n_t}$$

where S_{pl} is the saturation index of planar units, n_{pl} the number of planar units, S_{li} the saturation index of linear units, n_{li} the number of linear units, S_{pu} the saturation index of punctual units, n_{pu} the number of punctual units and n_t the total number of habitat units.

To determine species diversity in parks, we used four different species groups: vascular plant species (indigenous, naturalised as well as exotic species, including intra-specific taxa and varieties), butterflies, breeding birds and amphibians (see Hermy and Cornelis, 2000).

A stratified random sampling scheme of planar and linear habitat units was adopted to determine plant diversity. For herbaceous vegetation we used plots of $4\,\mathrm{m}^2$ and for trees and shrubs (>1.30 m) plots of $100\,\mathrm{m}^2$. Within each plot, we listed all vascular plant taxa that were present and the percentage cover was estimated using the decimal scale of Londo (1976). The

Table 1
Biodiversity indicators of the 15 study areas

	Ber	Vor	Col	Fra	Gaa	Gro	Sch	Ter	Zev	Pae	Pri	Bal	Zoe	Tru	Lop
Number of planar units	10	22	13	8	16	15	11	15	7	14	7	11	14	12	13
Saturation index planar units	0.53	0.59	0.51	0.39	0.39	0.35	0.38	0.51	0.43	0.53	0.38	0.48	0.37	0.52	0.50
Number of linear units	7	13	10	6	10	9	7	13	8	4	9	9	9	8	13
Saturation index linear units	0.47	0.70	0.62	0.52	0.47	0.57	0.38	0.71	0.49	0.16	0.67	0.60	0.51	0.62	0.73
Number of punctual units	2	3	2	2	3	3	2	3	1	2	1	1	3	3	4
Saturation index punctual units	0.02	0.33	0.09	0.18	0.32	0.10	0.12	0.08	0	0.19	0	0	0.36	0.40	0.42
Total number of habitat units	19	38	25	16	29	27	20	31	16	20	17	21	26	23	30
Saturation index total	0.45	0.61	0.52	0.41	0.41	0.39	0.35	0.55	0.43	0.42	0.51	0.51	0.42	0.54	0.59
Number of plant taxa	140	218	160	100	171	162	143	169	148	118	73	128	97	89	134
Diversity of plant taxa	3.45	2.81	3.26	2.89	3.33	3.15	3.2	3.13	3.45	3.29	2.95	2.64	2.98	2.93	3.23
Number of butterfly species	18	17	12	17	14	14	13	13	14	16	20	18	14	13	9
Number of amphibian species	1	6	2	3	4	6	1	4	1	0	2	5	5	-	3
Number of breeding bird species	27	36	18	12	24	26	15	42	16	13	39	20	27	42	36

Ber, St.-Bernarduspark; Vor, Vordenstein; Col, Coloma; Fra, Frankveld; Gaa, Gaasbeek; Gro, Groenenberg; Ter, Ter Rijst; Zev, Zevenbronnen; Pae, Paelsteenveld; Pri, Prins Karelpark; Bal, Balokken; Zoe, Municipal park Zoersel; Tru, St.-Trudopark; Lop, Municipal park Loppem.

number of samples taken was proportional to the total park area. For trees and shrubs we investigated 1% of the park area. That means 1 sample of $100\,m^2$ per ha. For the herbaceous vegetation we sampled 0.2% of the total area, i.e. five samples of $4\,m^2$ per ha. We arbitrarily assigned 30% of these samples to the linear units and 70% to the planar units. The number of samples was equally divided in relation to the proportion of the different planar or linear units. Within each habitat unit, the samples were chosen at random. Since many herbaceous species are only flowering during a short period, the inventory of herbaceous plants was performed twice, once in spring and once in summer. The highest cover value for each species in the two sampling periods was used. From the estimated dominance–abundance of the plant taxa, the Shannon–Wiener diversity index was computed for herbaceous vegetation and for trees and shrubs. For each species we used the average cover (%) of all plots. The diversity index of all plant species (H_p) was calculated as the weighted average of the index for trees and shrubs and the index for herbaceous plants:

$$H_P = \frac{H_{tr} \times n_{tr} + H_{he} \times n_{he}}{n_t}$$

where H_{tr} is the diversity index for trees and shrubs, n_{tr} the number of plots in woody vegetation, H_{he} the diversity index for herbaceous plants, n_{he} the number of plots in herbaceous vegetation and n_t the total number of plots.

Since censusing the importance (e.g. population size) of animal species is more time consuming than for plant species, we only took the species richness of these animal groups as a biodiversity indicator. The species number of butterflies was determined in two ways. Firstly, all species that were seen during the field survey of the plants, were recorded. Secondly, we searched during one extra day per 12.5 ha for additional species. The butterflies were identified as much as possible on sight, so they did not have to be captured. To determine the species number of breeding birds per park, we used existing data and complemented this by data of local ornithologists or local nature organisations. We added our own observations as well. In the same way, we determined the species richness of the amphibians. Since no population sizes were recorded, we did not calculate the Shannon–Wiener diversity index for the animal species.

In 1999 and 2000 we applied the described method to 12 different parks owned by the Flemish Region and managed by the Ministry of Flanders. We could also use the results of Hoogewijs (2001), who applied the same method to the municipal park of Zoersel and Verreet (2001), who applied it to the St.-Trudopark in Bruges. Including the data of the pilot project in the municipal park of Loppem (Hermy and Cornelis, 2000), the results of this paper refer to 15 study areas (see Fig. 1).

2.2. Biodiversity score

The biodiversity indicators were used to compare biodiversity in different parks. We made two biodiversity classes, based on habitat saturation and species richness, to summarise biodiversity in parks and to make a comparison easier (Table 2). The limiting values of the classes were chosen arbitrarily. If each class gets a value from 1 (very low) to 5 (very high), the sum of both classes gives a biodiversity score on 10. With these scores parks can be easily compared with each other.

2.3. Site characteristics

In addition to the 13 biodiversity indicators and the summarising biodiversity score, we calculated nine site characteristics of the parks to find out what ecological factors are affecting biodiversity (see Table 3). Park area, total length of linear elements and total number of punctual elements were calculated from the digitised maps. Forest area was calculated as the summed area of forest stands, plantations, shrub plantations and labyrinths; grassland area as the summed area of grasslands and tall herb vegetation and garden area as the summed area of gardens and ornamental plantations. Hardened and built area includes the buildings and all half-hardened or hardened areas (see Table 1 in Hermy and Cornelis, 2000).

The digital terrain model of Flanders (OC GIS Vlaanderen, 1997) was used to calculate the altitudinal difference between the highest and the lowest point of the park. The number of soil types in each park was counted from the digital soil map of Flanders (OC GIS Vlaanderen, 2001).

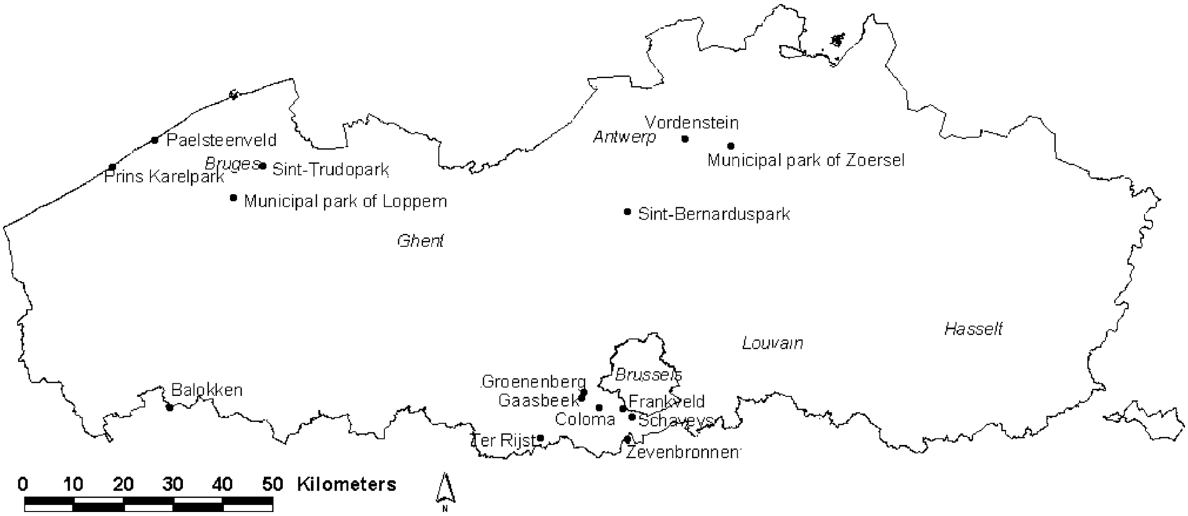

Fig. 1. Location of the 15 study areas in Flanders.

2.4. Analyses

To elucidate the role of these site characteristics, a direct and an indirect gradient analysis were performed using redundancy analysis (RDA) and principal components analysis (PCA), respectively. Spearman's rank correlation coefficients were calculated between the biodiversity indicators, the biodiversity score and the site characteristics to explore the relationships and factors affecting biodiversity in parks. The relationships between park area and number of habitat units, plant taxa and animal species were quantified by linear and logarithmic regressions. We attempted to separate the effect of the park area on the biodiversity indicators using partial correlation techniques. We also calculated the correlation coefficients between the number of plant taxa, plant diversity and the species number of butterflies, amphibians and breeding birds, on the one hand, and area, length or number of habitat units on the other, to find out what habitat units have the largest effect on the species richness or diversity. RDA and PCA were performed using Canoco for Windows 4.5 (ter Braak and Smilauer, 1998). The correlations and regressions were calculated with SPSS 10.0 (SPSS Inc., 1999).

3. Results

The 13 biodiversity indicators and the nine site characteristics of the 15 study areas are shown in Tables 1 and 3, respectively. The 15 study areas had a total area of 418 ha or an average of 27.9 ha per park. In 419 samples of 100 m^2 we found 118 tree and shrub taxa and in 2095 samples of 4 m^2 we found 448 herbaceous taxa. In total 497 taxa of vascular plants, belonging to

Table 2
Classification of habitat saturation and species richness into biodiversity classes

Class	Habitat saturation index	Species richness
Very high (5)	≥0.60	>200 plant taxa and >50 animal species[a]
High (4)	0.50–0.59	>200 plant taxa or >50 animal species
Moderate (3)	0.40–0.49	100–200 plant taxa and 25–50 animal species
Low (2)	0.30–0.39	100–200 plant taxa or 25–50 animal species
Very low (1)	<0.30	<100 plant taxa and <25 animal species

[a] Number of butterfly, amphibian and breeding bird species.

Table 3
Site characteristics of the 15 study areas (abbreviations of the parks, see Table 1)

	Ber	Vor	Col	Fra	Gaa	Gro	Sch	Ter	Zev	Pae	Pri	Bal	Zoe	Tru	Lop
Area (ha)	14.2	107.8	15.1	7.3	48.8	44.9	32.9	34.5	20.0	9.8	7.7	23.6	20.0	6.3	25.0
Length of linear elem. (km)	3.72	38.92	7.88	2.16	11.22	5.66	4.64	6.83	4.66	1.95	3.46	12.06	8.14	6.07	15.07
Number of punct. elem.	318	162	94	162	24	184	69	90	34	13	30	113	32	65	120
Forest area (ha)	4.2	79.7	6.1	1.8	29.2	28.9	23.6	9.1	7.8	4.7	4.3	4.8	12.2	3.6	15.1
Grassland area (ha)	6.5	13.1	4.9	4.4	10.8	14.1	8.8	21.4	7.0	3.0	2.3	14.2	3.8	1.6	7.4
Garden area (ha)	0.0	2.0	2.2	0.0	1.7	0.1	0.0	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.1
Hardened/built area (ha)	3.3	0.9	1.0	0.7	5.3	1.4	0.3	1.7	0.4	1.7	0.4	1.9	3.1	0.5	1.4
Altitudinal difference (m)	7	3	18	19	30	30	37	23	22	1	0	3	3	2	2
Number of soil types	1	18	8	11	14	20	19	17	13	2	7	8	7	6	11

252 genera, were listed. Three hundred and ninety three tree species belonged to the wild flora of Flanders (Biesbrouck et al., 2001), which is 29.9% of the total number of wild plant species still occurring in Flanders. We found 82 species of breeding birds, 28 species of butterflies and 8 species of amphibians. This is 48.5, 38.9 and 61.5% of the species number of breeding birds, butterflies and amphibians in Flanders, respectively. We mapped 48 of the 56 possible habitat units, divided into 27 planar, 17 linear and 4 punctual units.

3.1. Habitat diversity

The number of mapped habitat units per park varied between 16 and 38. Three units appeared in all study areas (leafy regular high forest, lawn and single tree or shrub). Ponds were present in 13 and shrub plantations, buildings, half-hardened roads and half-hardened paths each in 12 study areas. Leafy, regular high forest was the most important planar habitat unit: it took up 146 ha or 35% of the total area. Lawn came second with 67 ha or 16%. Natural banks of a watercourse had a total length of 15.5 km and were the most important linear unit. Other important linear units were alleys (15.0 km), half-hardened paths (12.9 km), tree rows (12.4 km), natural banks of a water feature (12.1 km) and ditches (10.4 km). We also mapped 1232 single trees or shrubs.

After calculation of the diversity indices, we found a total saturation index varying between 0.35 and 0.61. The saturation index of planar units varied between 0.35 and 0.59, that of linear units between 0.16 and 0.73 and that of punctual units between 0 (if only 1 type was present) and 0.42 (see Table 1).

3.2. Species diversity

The number of vascular plant taxa per park varied between 73 and 218 and the Shannon–Wiener diversity index between 2.64 and 3.45. All parks had ten species in common: *Acer pseudoplatanus*, *Cerastium fontanum*, *Holcus lanatus*, *Lolium perenne*, *Plantago major*, *Poa annua*, *Ranunculus repens*, *Taraxacum* spp., *Trifolium repens* and *Urtica dioica*. If the percentage cover of the taxa is taken into account, *Lolium perenne*, *Holcus lanatus*, *Trifolium repens* and *Poa trivialis* were the most important herbaceous species and *Fagus sylvatica*, *Acer pseudoplatanus*, *Quercus robur* and *Fraxinus excelsior* were the species of trees with the highest cover.

The number of observed butterfly species varied between 9 and 20. Three species appeared in all study areas (*Pararge aegeria*, *Pieris napi* and *P. rapae*). *Inachis io* was found in 14 parks and *Vanessa atalanta*, *Polygonia c-album* and *Pieris brassicae* were found in 13 of the 15 study areas.

In two parks no amphibians were found (in the St.-Trudopark amphibians were not surveyed). In two other parks six species appeared and in another two parks we found five species. *Bufo bufo* was present in 11 parks, *Rana temporaria* in 10 and *R. esculenta* in 7.

The lists of breeding birds are probably incomplete. We could use a recent survey for only five parks. For three parks we used ring and catch results that are probably an overestimation of the number of breeding bird species. For the seven other parks we used our own observations which are probably incomplete and thus an underestimation of the real species number. Nonetheless, *Parus major*, *Turdus merula* and *T. philomelos* were observed in all study areas. *Erithacus rubecula*, *Phylloscopus collybita* and *Troglodytes troglodytes* appeared in 14 parks.

3.3. Relationships

The triplot of the redundancy analysis on the 13 biodiversity indicators with the nine site characteristics used to extract patterns from the explained variation is shown in Fig. 2. The first and second axis explain, respectively, 83.5 and 4.6% of the variance. The scores of the 15 study areas on the first two axes of the RDA are positively correlated ($P < 0.001$) with the scores on the first two axes of a principal components analysis, suggesting that the calculated site characteristics are adequately explaining the variation of the biodiversity indicators. The variation on the first axis is mainly explained by a combination of total park area, forest area, grassland area, garden area, total length of linear elements and number of soil types (Fig. 2). Since forest, grassland and garden area, total length of linear elements and number of soil types are all positively correlated with park area ($P < 0.02$), we can conclude that park area is the main factor explaining the variation in biodiversity indicators. Therefore it is not surprising that park area is positively correlated with the number of planar units, the number of linear

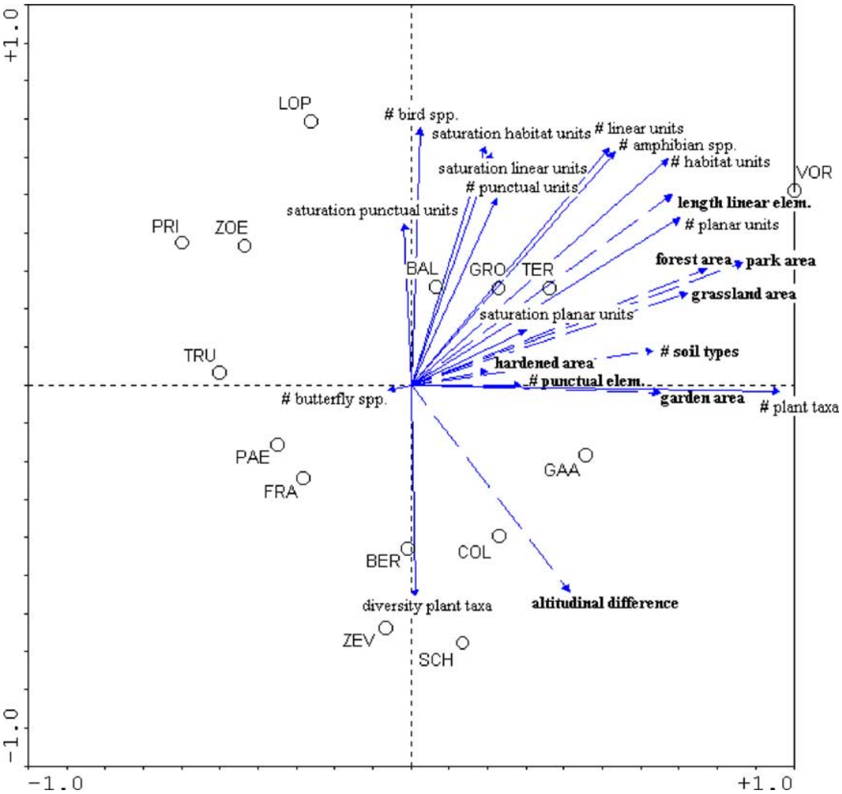

Fig. 2. RDA-triplot of 13 biodiversity indicators (normal font), nine additional characteristics (in bold) and 15 study areas (in capitals; for abbreviations, see Table 1).

units, the total number of habitat units, the number of plant taxa and the number of amphibians (see Table 4 and Figs. 3–5).

At first sight the altitudinal difference between the highest and the lowest point of the park and the number of soil types in the park have a positive effect on the number of plant taxa (Table 4). They both contribute to the environmental variety in which a lot of plants can find their optimum. However, altitudinal difference and number of soil types both depend on park area and after controlling for area, the correlation with number of plant taxa disappears.

Some biodiversity indicators are related to each other (Table 5). A significant positive relationship exists between total number of habitat units and number of plant taxa, number of amphibian species and number of breeding bird species, although number of plant taxa and species number of amphibians and breeding birds are not significantly related with one another. Total number of habitat units, number of plant taxa and number of amphibian species are all correlated with park area ($P < 0.05$). A partial correlation controlled for park area gives no longer a significant relationship between number of habitat units and number of plant taxa or amphibian or breeding bird species (Table 6).

Also no significant relationship was found between diversity of habitat units (expressed as saturation index) and diversity of plants. Remarkable is the lack of a significant relationship between the number of plant taxa and the Shannon–Wiener diversity index for plants (Table 5). However, the number of plant taxa and the diversity index for plants are positively correlated if we control for park area (Table 6). In the normal correlation as well as in the partial correlation, no significant relationships were found between number and saturation index of planar units and all habitat units together, although there is one between number and saturation of linear units and between

Table 4
Spearman's rank correlation coefficients between biodiversity indicators and site characteristics in 15 parks

	Number of planar units	Sat. planar units	Number of linear units	Sat. linear units	Number of punct. units	Sat. punct. units	Number of habitat units	Sat. habitat units	Number of plant taxa	Div. plant taxa	Number of butt. spp.	Number of amph spp.	Number of bird spp.
Area (ha)	0.68**	−0.12	0.64*	0.13	0.44	0.10	0.71**	0.01	0.83**	0.05	−0.21	0.61*	0.12
Length of linear elem. (km)	0.55*	0.12	0.83**	0.52*	0.53*	0.35	0.78**	0.52*	0.44	−0.25	−0.32	0.68**	0.40
Number of punct. elem.	−0.01	0.16	0.13	0.31	0.16	−0.07	0.14	0.17	0.28	−0.20	0.07	0.34	0.07
Forest area (ha)	0.69**	−0.22	0.60*	0.08	0.50	0.28	0.71**	−0.05	0.73**	0.11	−0.33	0.53*	0.09
Grassland area (ha)	0.44	−0.04	0.52*	0.19	0.20	−0.22	0.53*	0.05	0.77**	−0.06	−0.09	0.56*	0.04
Garden area (ha)	0.71**	0.18	0.43	0.04	0.43	0.46	0.57*	0.11	0.45	0.18	−0.25	0.26	−0.10
Hardened area (ha)	0.48	0.14	0.21	−0.16	0.31	0.11	0.39	−0.02	0.20	0.21	0.13	0.27	0.09
Altitudinal difference (m)	0.17	−0.36	0.03	−0.31	0.07	−0.19	0.09	−0.53*	0.65**	0.28	−0.29	0.10	−0.34
Number of soil types	0.39	−0.35	0.41	0.17	0.28	0.01	0.42	−0.19	0.71**	−0.10	−0.30	0.44	−0.08

* Two-tailed significance: $0.01 < P \leq 0.05$.
** Two-tailed significance: $P \leq 0.01$.

Table 5
Spearman's rank correlation coefficients between biodiversity indicators in 15 parks

	Number of planar units	Sat. planar units	Number of linear units	Sat. linear units	Number of punct. Units	Sat. punct. units	Number of habitat units	Sat. habitat units	Number of plant taxa	Div. plant taxa	Number of butt. spp.	Number of amph spp.	Number of bird spp.
Number of planar units	1												
Saturation planar units	0.17	1											
Number of linear units	0.56*	0.07	1										
Saturation linear units	0.16	0.17	0.75**	1									
Number of punctual units	0.74**	0.08	0.52*	0.35	1								
Saturation punctual units	0.53*	0.13	0.18	0.10	0.80**	1							
Number of habitat units	0.89**	0.18	0.83**	0.51	0.82**	0.51	1						
Saturation habitat units	0.14	0.66**	0.57*	0.80**	0.19	0.11	0.44	1					
Number of plant taxa	0.60*	0.18	0.52*	0.06	0.30	−0.05	0.57*	0.06	1				
Diversity plant taxa	−0.05	0.08	−0.17	−0.50	−0.05	−0.12	−0.16	−0.27	0.29	1			
Number of butterfly species	−0.30	0.01	−0.34	−0.22	−0.55*	−0.45	−0.44	−0.14	−0.25	−0.27	1		
Number of amphibian species	0.59*	−0.23	0.60*	0.52	0.51	0.28	0.66**	0.17	0.32	−0.63*	0.03	1	
Number of breeding bird spp.	0.25	0.19	0.59*	0.69**	0.49	0.18	0.53*	0.67**	−0.02	−0.27	−0.10	0.43	1

* Two-tailed significance: $0.01 < P \leq 0.05$.
** Two-tailed significance: $P \leq 0.01$.

Table 6
Partial correlation coefficients between biodiversity indicators after controlling for park area in 15 parks

	Number of planar units	Sat. planar units	Number of linear units	Sat. linear units	Number of punct. units	Sat. punct. units	Number of habitat units	Sat. habitat units	Number of plant taxa	Div. plant taxa	Number of butt. spp.	Number of amph spp.	Number of bird spp.
Number of planar units	1												
Saturation planar units	0.30	1											
Number of linear units	0.11	0.15	1										
Saturation linear units	−0.19	0.04	0.87**	1									
Number of punctual units	0.62*	−0.02	0.41	0.15	1								
Saturation punctual units	0.52	−0.06	0.17	−0.06	0.78**	1							
Number of habitat units	0.77**	0.25	0.70**	0.40	0.80**	0.55	1						
Saturation habitat units	0.12	0.65*	0.73**	0.71**	0.10	0.05	0.49	1					
Number of plant taxa	0.18	0.41	0.12	−0.06	0.08	−0.27	0.19	0.03	1				
Diversity plant taxa	0.09	0.11	−0.08	−0.34	0.26	0.04	0.06	−0.26	0.63*	1			
Number of butterfly species	−0.36	0.02	−0.45	−0.13	−0.68**	−0.49	−0.60*	−0.05	−0.47	−0.45	1		
Number of amphibian species	0.19	−0.39	0.37	0.49	0.26	0.14	0.37	0.10	−0.31	−0.61*	0.02	1	
Number of breeding bird spp.	0.08	0.12	0.75**	0.69**	0.33	0.04	0.53*	0.63*	−0.22	−0.10	−0.00	0.27	1

* Two-tailed significance: $0.01 < P \leq 0.05$.
** Two-tailed significance: $P \leq 0.01$.

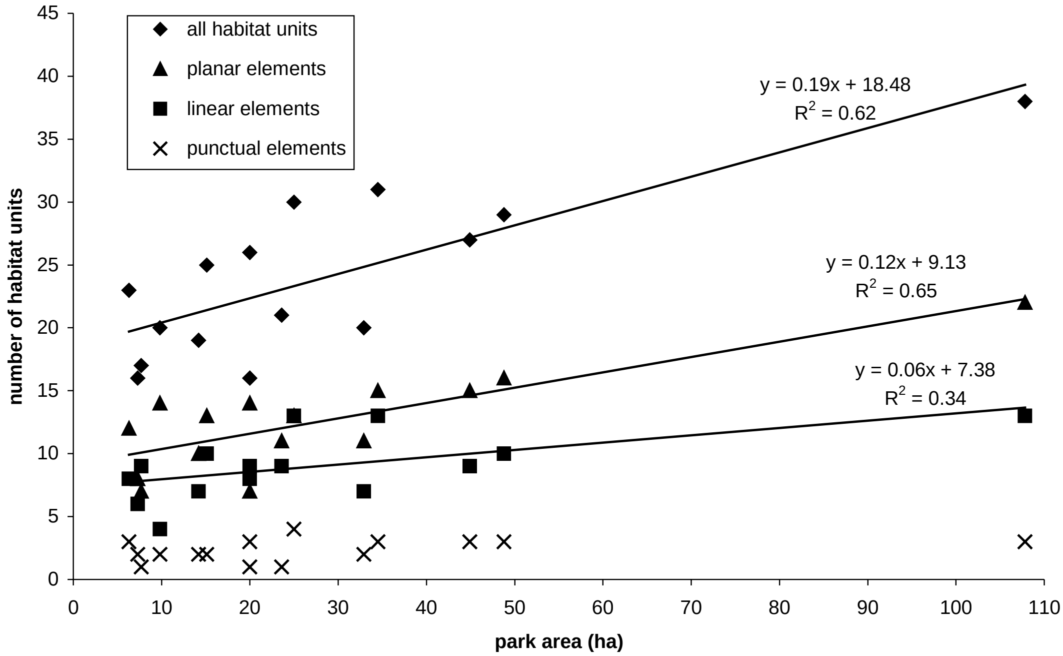

Fig. 3. Relationship between the number of habitat units and the park area (only significant linear regressions are shown).

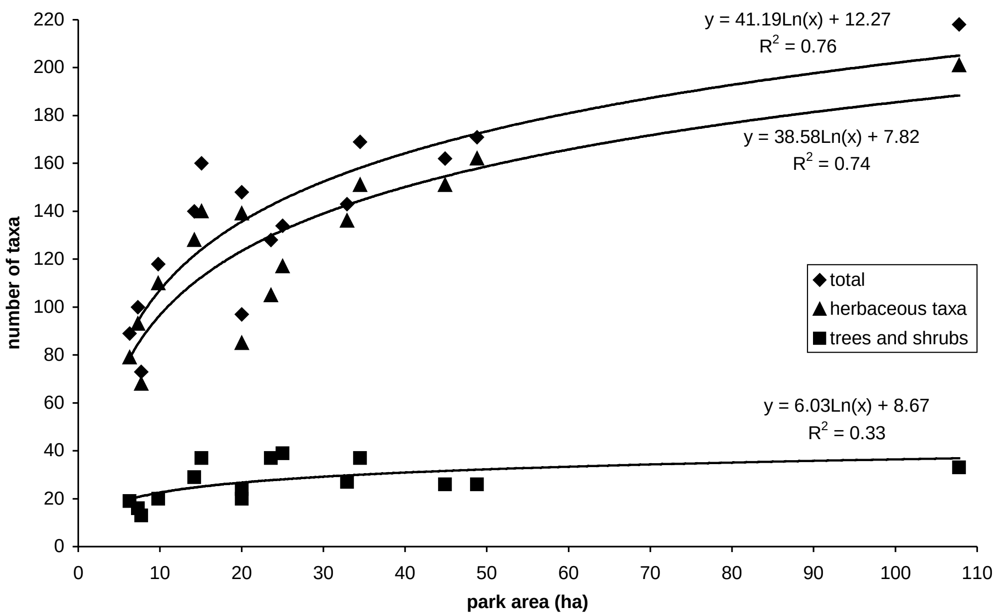

Fig. 4. Relationship between the number of plant taxa in the samples and the park area.

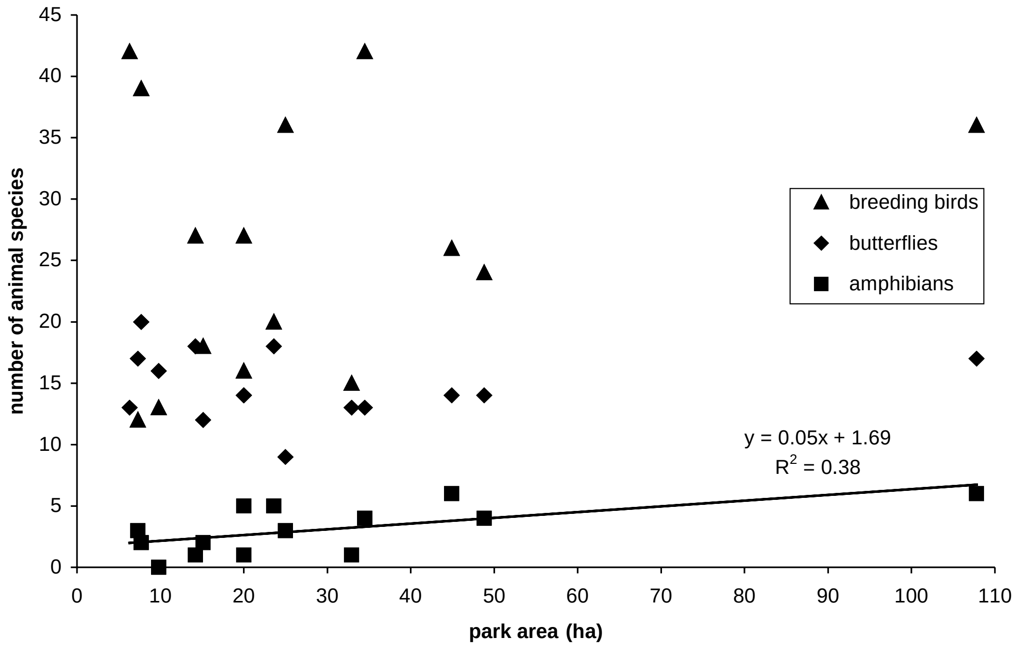

Fig. 5. Relationship between number of animal species and park area (only significant linear regressions are shown).

Table 7
Spearman's rank correlation coefficients between species number or diversity and the area, length or number of habitat units in 15 parks (only habitat units with significant correlations are listed)

	Number of plant taxa	Plant diversity	Species number of butterflies	Species number of amphibians	Species number of breeding birds
Planar units (area)					
Park wood	0.53*	−0.04	0.19	0.32	0.35
Leafy, regular high forest	0.64**	0.17	−0.10	0.40	0.15
Orchard	0.54*	0.22	−0.42	0.08	−0.23
Forest grassland	0.16	−0.29	−0.41	0.12	0.66**
Hay meadow	0.26	−0.24	0.56*	0.52*	0.30
Pasture	0.59*	−0.09	−0.30	0.68**	0.51
Tall herb vegetation	−0.10	−0.60*	0.68**	0.61*	0.05
Building	−0.05	0.11	−0.03	−0.06	0.74**
Linear units (length)					
Tree row	0.37	−0.33	−0.01	0.54*	0.14
Sheared hedge	0.43	−0.05	−0.60*	0.43	0.23
Road verge	0.64**	0.27	−0.47	0.34	0.16
Semi-natural bank of a water feature	−0.02	0.14	−0.60*	−0.27	0.54*
Natural bank of a watercourse	0.08	−0.61*	−0.05	0.63*	0.11
Brook	−0.06	−0.53*	−0.14	0.38	0.53*
Wall	0.04	−0.06	0.27	−0.04	0.70**
Punctual units (number)					
Pool	0.23	−0.28	−0.08	0.52*	−0.16
Icehouse	−0.08	−0.09	−0.60*	−0.12	0.62**

* Two-tailed significance: $0.01 < P \leq 0.05$.
** Two-tailed significance: $P \leq 0.01$.

Table 8
Biodiversity scores in the 15 study areas

Park	Habitat saturation index	Species richness	Biodiversity score
St.-Bernarduspark	Moderate	Moderate	6
Vordenstein	Very high	Very high	10
Coloma	High	Moderate	7
Frankveld	Moderate	Moderate	6
Gaasbeek	Moderate	Moderate	6
Groenenberg	Low	Moderate	5
Schaveys	Low	Moderate	5
Ter Rijst	High	High	8
Zevenbronnen	Moderate	Moderate	6
Paelsteenveld	Moderate	Moderate	6
Prins Karelpark	High	High	8
Balokken	High	Moderate	7
Municipal park Zoersel	Moderate	Low	5
St.-Trudopark	High	High	8
Municipal park Loppem	High	Moderate	7

number and saturation of punctual units (Tables 5 and 6).

From Table 7 it is clear that the number of plant taxa is strongly related with the length of road verges and the area of leafy, regular high forest, park wood, orchards and pastures. The number of butterfly species is positively related with the area of tall herb vegetation and hay meadows. Amphibians are related with the area of pastures, hay meadows and tall herb vegetation, the length of natural banks of watercourses and tree rows and the number of pools. The number of breeding birds is related with the area of forest grasslands but also with buildings, walls and icehouses.

In Table 8 each park gets a biodiversity score based on the classification of Table 2. Vordenstein is the only park with a maximum score, all other parks get a score between 5 and 8. The biodiversity score is highly correlated with the total saturation index ($r_s = 0.89$; $P < 0.01$) and with the sum of the number of butterfly, amphibian and breeding bird species ($r_s = 0.66$; $P < 0.01$), but it is not significantly correlated with the number of plant taxa nor with park area.

4. Discussion

The high numbers of species that were found during the surveys, particularly in relation to the number of species existing in Flanders, already suggest that urban and suburban parks in Flanders are characterised by a high biodiversity. Moreover, with the randomly stratified samples only part of the total plant species richness was recorded. In the St.-Trudopark, for instance, 89 plant taxa were found in 32 samples of 4 m^2 and 6 samples of 100 m^2, whereas a survey of all plant taxa in the park resulted in 339 taxa (Verreet, 2001). So for that park only 26.3% of the species richness was found through sampling. The St.-Trudopark is only 6.3 ha. In larger parks a larger amount of the species richness will probably be found, since the number of additional taxa decreases with an increasing number of samples or an increasing area (Fig. 4). One of the main reasons for this high species richness is that parks generally consist of different habitats (grasslands, forests, plantations, water features, gardens, banks, hedges, etc.). The planted, cultivated and exotic species and the different collections (e.g. *Narcissus*, *Rhododendron*, *Rosa*, *Dahlia*, *Hydrangea*) also contribute to these high numbers. The use of these varieties and cultivars in the calculation of the diversity indices is subject for discussion from nature conservation point of view, although they are a substantial part of the species spectrum in parks. This diversity, which is the result of selective breeding, is an integral part of biodiversity according to the international biodiversity convention (UNEP, 1992). May be a distinction should be made between native (naturally evolved) and artificial (human generated) biodiversity like Angermeier (1994) suggested. Anyway, the use of cultivated species and varieties did not influence the relationships between the biodiversity indicators. The same significant relationships were found if the number of wild species (based on the list of Biesbrouck et al., 2001) or the number of genera was used instead of the total number of taxa. The number of plant taxa is highly positively correlated with the number of wild plant species ($r_s = 0.94$; $P < 0.01$) and the number of plant genera ($r_s = 0.95$; $P < 0.01$). So, reducing the plant surveys to the wild species or the genera would be less time consuming. Although, there would probably be a difference with a full survey, considering, for instance, the 2600 varieties of roses in Coloma, of which only 31 were found in the plots. Of course, a full survey would take much more time. To make a complete species list (even without intra-specific taxa and varieties), many years of research are necessary,

like the research in the forest of Ename has shown (Hermy et al., 1996).

Besides the species level, the method for the measurement of biodiversity in parks takes also the habitat level into account. Mapping the habitat units, from which the diversity can be deduced, forms a good base for the drawing of management plans and may be a simple surrogate for species number. One would expect a positive relationship between the variety (number/diversity) of habitat units and the richness and diversity of species (cf. Hobbs, 1988; Rosenzweig, 1995; Begon et al., 1996; Honnay et al., 1999). However, the results show no significant relationship between habitat diversity and plant diversity when the biodiversity indicators are calculated based on the Shannon–Wiener index. There is a significant positive relationship between number of plant taxa and number of habitat units, but this relationship disappears when the correlation is controlled for park area.

It is clear that park area is the main factor explaining the variation in biodiversity indicators. The number of habitat units, the number of plant taxa and the number of amphibian species all depend on park area and could be predicted based on this area (see Figs. 3–5). Similar relationships were found between the plant species number and the area of Flemish forests (Hermy and Honnay, 1998) or the area of European cities (Pysek, 1993). A positive correlation between area, number of plant species and number of habitat types was also found by Kohn and Walsh (1994). Fernández-Juricic and Jokimäki (2001) found that area was an important predictor of the bird species number in Spanish, Finnish, Japanese, American, Slovakian and Polish parks. In this study, we did not find such a relationship for breeding birds, probably due to the incomplete species lists.

Remarkable is that at first sight no significant relationship was found between plant diversity and number of plant taxa, although the Shannon–Wiener diversity index takes the number of taxa into account. The relationship becomes significantly positive if it is controlled for park area, with which the number of taxa is highly correlated. The number of habitat units however is not related to the saturation index of habitat units, nor in the normal correlation, nor in the partial correlation. Apparently the evenness with which habitat units are distributed over the park or the plant cover is more important than the number of habitat units or plant taxa in the calculation of the Shannon–Wiener diversity index. To test the importance of the habitat abundance, we omitted in each park the planar unit with the highest area and recalculated the habitat saturation index. In that case the relationship between the saturation index and the number of habitats becomes significantly positive ($r_s = 0.71$; $P < 0.01$). In the same way we omitted the herbaceous and the woody species with the highest cover and recalculated the plant diversity index. Without the most abundant species, the species number becomes also significantly correlated to the species diversity index in the normal correlation ($r_s = 0.53$; $P < 0.05$). So species or habitats with a high abundance have a high impact on the Shannon–Wiener diversity index. This corresponds with the statement of Dougall and Dodd (1997) who said that diversity as quantified by the Shannon–Wiener diversity index is not a true indication of species presence due to the incorporation of the abundance component in the formula which can overcompensate for richness.

The main conclusion of this study is that urban and suburban parks may be considered important 'hotspots' of biodiversity in cities, like Fernández-Juricic and Jokimäki (2001) already concluded. This is particularly true if, as here, they consist of different more or less semi-natural habitats and are quite large. The studied parks had an average area of 27.9 ha which is far above the average of all parks in Flanders and is quite high for an urban or suburban park. The results of this study showed that park area has a positive impact on biodiversity, so larger parks can contribute more to the conservation of biodiversity then smaller ones, although small parks can play an important role as stepping stones between isolated (semi-)natural habitats.

The biodiversity score, which is introduced in this paper as a summary of habitat saturation and species richness, makes it very easy to compare biodiversity in different parks. It reduces the 13 biodiversity indicators to one number and is not only a summary but also an evaluation of biodiversity in parks on a scale from 1 to 10. Since it is not correlated with park area, it might be considered as a reliable indicator for comparing biodiversity in parks of different area.

In our study the high species richness in Ter Rijst, Prins Karelpark and St.-Trudopark might be exaggerated due to the possible overestimation of the number of breeding bird species in those parks. The score

of Prins Karelpark and St.-Trudopark is actually very low if only the number of plant taxa is taken into account. So, for a proper evaluation and comparison of biodiversity in parks, only correct data should be used. Besides, it is clear that the results will always depend on the intensity of the survey and the number of taxa involved.

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